The Problem of EMP Protecting Critical Civilian Infrastructure. Who Is to Blame and What Is to Be Done?

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"The current state of EMP protection is random, disoriented and uncoordinated"
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Abstract: The problem of the destructive effects of High-Altitude Electromagnetic Pulse (HEMP or EMP) on electronic and electrical equipment has been well known for more than 80 years, and almost 60 years ago, all the data on this effect was declassified. Hundreds of millions of dollars have been spent on EMP research; hundreds of scientific reports, dissertations, and guidelines have been written. Dozens of standards have been prepared and published. There are dozens of types of protection means available on the market. However, in no country in the world has critical civilian infrastructure actually been protected. The reasons for this are analyzed in this article, and specific measures to solve the problem are also proposed.

Keywords: high-altitude electromagnetic pulse, EMP, HEMP, critical civilian infrastructure, protection means

I. INTRODUCTION

The ability of a powerful electromagnetic pulse (EMP) to destroy all electronics has been known to nuclear physicists since the first nuclear explosion was performed in 1945 on the Alamogordo range, New Mexico (project "Trinity"). Upon the explosion, many apparatus that was meant to monitor the explosion parameters became inoperative. Upon all further test explosions performed in all countries, EMP was registered precisely, and was followed with the analysis and study of the parameters.

An additional experimental high-altitude nuclear explosion (300 kt yield at altitude 290 km) named "K-3" was performed in the Soviet Union (at Kazakhstan, 180 kilometers west of Dzhezkazgan town) on Oct. 22, 1962. According to data, published by General V. M. Loborev (Fig. 1), the EMP impact caused failures in the operation of air defense radar located about 1,000 km away. An underground power cable with a length of 1,000 km, passing at a depth of about 1 meter and connecting towns Tselinograd and Alma-Ata, was put out of action. Breakdowns of ceramic insulators resulting in short-circuits were observed on 35-kV electric overhead power lines, in some areas. The insulators were so damaged that the wires fell to the ground. Electromagnetic pulse caused fires due to short-circuit in electric appliances. A power generator which was connected to an underground power cable was knocked out of service at one of power plants in Karaganda town, relay protection (even old electromechanical type, not modern EMP sensitive microprocessor based!) was triggered resulting in switching the power generator off at another power plant. A slow geomagnetic component of EMP induced a short current pulse with an amplitude of several thousand Amps, as well as a long (more than 20 sec) current pulse, rated 4A DC. This led to diesel-generator damage and triggering of protection devices mounted over a 570 km above-ground telephone line. There is also information about some breakages of electronic equipment, occurred at Baikonur Cosmodrome. At the same time, it should be taken into account that the level of electronics in the USSR in 1962 was incomparably lower than in the West today. That is, the breadth of application of electronics, its sensitivity (i.e., susceptibility to EMP) were incommensurate with today. If such a test were carried out today, it would lead to the complete collapse of a large part of the country.

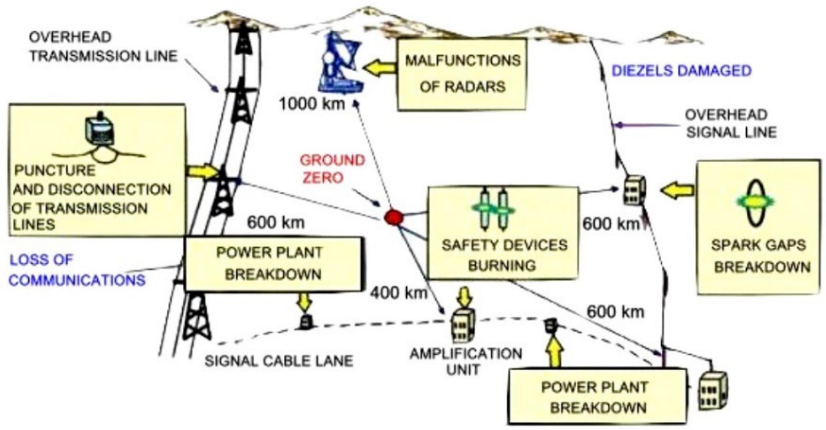

Fig. 1. Damaged electric equipment affected by HEMP during nuclear high-altitude test explosion performed under "K-3" project in Kazakhstan in 1962 (based on data published in V. M. Loborev's report presented at EUROEM International conference in France in 1994).

Beginning in the 1970s (almost 60 years ago), that subject has been unclassified. At that time, dozens of Western scientific and technical reports, prepared by numerous military and civilian organizations (working at the military request), were devoted to different aspects of EMP impact on electrical equipment and electronics. Since then, the electromagnetic pulse had been officially recognized as one of the damage effects of nuclear weapons, along with the detonation wave, the temperature, the light and the radioactive emission.

So, the problem of the destructive impact of EMP on electrical and electronic equipment has been known for many decades [1], and yet, as Professor George H. Baker in Testimony before the House Committee on National Security and House Committee on Oversight and Government Reform (May, 2015) correctly points out: "*the current state of EMP protection is random, disoriented, and uncoordinated*."

But why? Aren't there dozens of scientific reports on this topic?
Aren't there standards?
Isn't there protection equipment available on the market?

No, all of this exists, but critical civil infrastructure around the world has remained unprotected for all these decades from first nuclear explosion.

II. Who Is to Blame?

Today, there are two trends in the world that are on opposite ends. On one end, you have dozens of governments and private organizations with budgets in the hundreds of millions of dollars tackling this issue (for example, in the US), and on the other end - a complete lack of such organizations in most countries (for example, in Israel). What connects these two extremes is the total absence of a clear organizational structure in this field, which doesn't exist in any country today. And that's why even multi-million-dollar investments in this problem in the US haven't brought the country any closer to solving it; if anything, they've just added more chaos.

There are two aspects to the problem: technical and organizational.

The technical aspect includes four problems:

1. The uncertainty in determining the key parameters of EMP that should be used as a guide when choosing the protection level for civilian critical infrastructure facilities (CIF). For military equipment,

the maximum possible EMP parameters are adopted under the most adverse conditions, since important military equipment must be 100% protected against EMP in all possible external conditions and environments of its use. For civilian equipment, such approach is unacceptable for a number of reasons, which are beyond the scope of this article, and moreover, they have already been discussed in detail by us earlier in [1, 2, 3].

2. The lack of a simple and clear set of guidelines for technical specialists at CIF who are not experts in the field of EMP, as well as the absence of interpretation of special standards in this area, and a summarizing guide on how to apply the many existing standards in practice for choosing the protection level and specific protective measures for specific CIF equipment [3]. So, what do these specialists have today? Dozens of scattered military and civilian standards with dozens of tables and graphs that could make an EMP specialist's head spin!

3. The long-standing and endlessly repeated concept of CIF protection is based on the idea that there's no need to develop protective measures specifically for CIF, since there's already a wide range of protective devices available on the market designed for special government facilities and military equipment according to military standards. The flaws of this concept have been thoroughly discussed by us earlier in numerous articles and books, including [2, 3].

4. Fake reports from leading global research and manufacturing companies about successes and achievements in developing and producing protection means against EMP, as well as electronic equipment resistant to such EMPs. Some of these fakes are described in detail in [2, 3, 4]. Many well-known organizations are mentioned in these publications, in particular:

4.1. Sandia National Laboratories (SNL) with its development of a "*fundamentally new*" transient voltage suppressor for protecting power systems from nuclear EMP for $6.5 million, Fig. 2;

Fig. 2. One of the fakes spread by SNL that their microscopic element is a revolution in technology and now you can "sleep well": a national electric grid is protected well against EMP [2].

4.2. USA Department of Homeland Security (DHS) with its outstanding work on "*improve understanding of the effect of EMP events*" for 22 million 750 thousand dollars, Fig. 3. It would be really interesting to find out what new EMP "*effects of EMP events*" the DHS employees managed to discover for 22 million dollars that have remained unknown for the last 50 years?

S&T Project	Purpose	Funding ($)	Funds Obligation Timeline
Focus Area 2: Electromagnetic Pulse and Geomagnetic Disturbance Resilience Capabilities			
CISRR - EMP and GMD Resiliency	Improve our understanding of the effects of EMP/GMD events on communications infrastructure (and other critical infrastructure) and drive research activities to provide practical, data-driven, specific, and actionable information, concepts, techniques, technologies, and tools to critical infrastructure owners and operators to implement to protect their current and future communication systems from the impacts of an EMP event.	$22,750,000	FY 2022-2025

Fig. 3. The budget of the Department of Homeland Security to "*improve understanding*" of the problem of critical infrastructure resilience after 60 years of careful study.

It would be really interesting to find out what new EMP "*effects of EMP events*" the DHS employees managed to discover for 22 million dollars that have remained unknown for the last 50 years? Probably, it was the discovery of the possibility of electromagnetic shielding for protection against EMI! Yes, "Best Practices for Protection of Mission Critical Equipment," consists of a "revolutionarily new" recommendation to use electromagnetic shielding to protect against electromagnetic fields, Fig. 4.

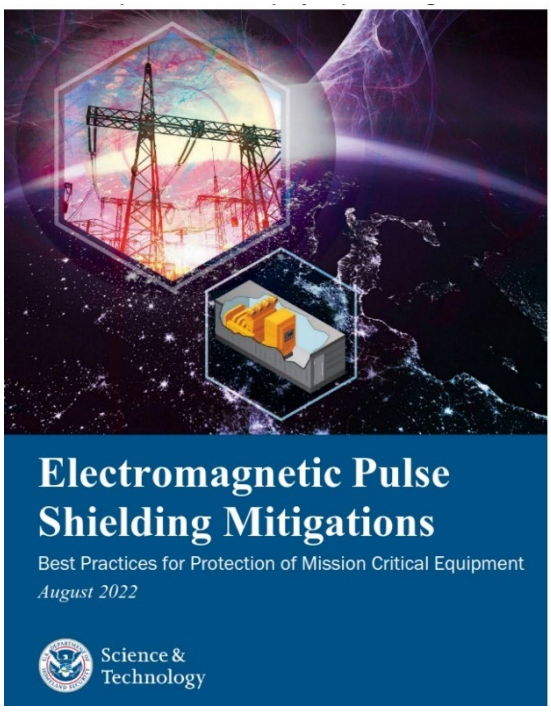

Fig. 4. "Outstanding achievement" of the DHS Science and Technology Directorate.

And it would also be interesting to know if the DHS employees are familiar with Michael Faraday's work on electromagnetic shielding, which he did 180 years before the "discovery" of DHS and without 22 million dollars?

4.3. Schweitzer Engineering Laboratories (SEL) with its numerous fakes about the requirements for the protection level of microprocessor-based protective relays, methods for testing their resistance to EMP, and the interpretation of the results, supposedly showing the absolute immunity of SEL products to EMP;

4.4. General Electric Co., which presented in its report "Control House and Relay Design Consideration for EMP Resiliency" at a scientific conference in Texas a completely incorrect method for testing EMP resilience and test results of their equipment, allegedly confirming this resilience;

4.5. MPE Limited - well-known EMP filter manufacturer, tests them on equipment that doesn't meet the parameters required by EMP standards. And their specialists understand this well but still find a way to justify it.

4.6. Research report No. SAND2020-3824 "Testing of Photovoltaic Modules for High-Altitude Electromagnetic Pulse" at Sandia National Laboratories is another example of how, in the conclusions of an absolutely correct but very limited study, the researcher doesn't specifically highlight and doesn't emphasize that the results of their work have very limited applicability, since they only relate to a single PV panel, and the conclusion about PV resilience cannot be extended to an entire installation, consisting of hundreds electrically connected panels. Generally speaking, the question arises here about the value of such research, considering that PV installations never consist of just a single PV panel, but contain hundreds or even thousands of such panels, electrically connected together into a common system. The huge total area of a real PV installation means that the total energy absorbed over such an area and the induced total voltage at a HEMP electric field strength of 50 kV/m, do not in any way compare to the energy and voltage applied to a single PV module in a test setup simulator. Unfortunately, this is not mentioned at all in the SNL report, and already many scientific and advertising publications have appeared referencing this report, claiming that PV installations are HEMP-resistant.

The consumer usually doesn't have the ability to check the accuracy of the information provided by such companies and is forced to take it on faith and buy the expensive advertised products, being confident in their effective protection, which later might turn out to be a nasty surprise in a critical situation. But that's just one side of the fake news problem. The other side is that messages about achieved successes and equipment reliably protected from EMP make it seem unnecessary to develop actually needed protection tools and secure electronic equipment for civilian infrastructure. Why invest money in developing something that's already successfully developed and produced by well-known companies? So, it seems like there's no problem at all.

The organizational aspect also includes four main issues:

1. The interdepartmental nature of the problem of protection against EMP, where it remains unclear which agency or ministry this problem belongs to. On one hand, it's a matter of defense against a military weapon, so it seems like a job for the Department of Defense (DoD), but on the other hand, it relates to civilian infrastructure, and the people responsible for keeping that infrastructure running, not the military, should be taking care of it.

The Department of Energy (DoE) says that we need to develop missile defense and protect the country from the possibility of a nuclear explosion over its territory, rather than from the consequences of that explosion, which isn't really the DoE problem. At first glance, this approach seems reasonable, but in practice, it doesn't hold up.

In [2, 3] show that using modern launch systems built as standard shipping containers, transported by civilian container ships, it's possible to launch a tactical missile with a nuclear warhead to an altitude high enough for an EMP directly from a country's commercial port. Military means cannot intercept such a missile.
Experts in the nuclear industry (in the US this field falls under the DoE, but in other countries it's a separate government agency) agree that EMP is one of the damaging effects of a nuclear explosion specifically, and not just any explosion, and its parameters depend on the characteristics of the nuclear device. However, they can't be responsible for the protection of specific civil infrastructure facilities and equipment, since they simply aren't familiar with them.

The Department of Homeland Security (DHS) points to the DoE and the DoD, and meanwhile, makes money on reports and recommendations that don't really affect the situation. And so on… Nobody voluntarily wants to take responsibility for this issue that most people barely understand.

2. Nowadays, decisions and recommendations on the protection of critical infrastructure are made by politicians, heads of ministries and agencies, and managers who aren't technical experts and aren't familiar with purely technical issues, nor do they have experience in specific technical areas like power engineering, water supply, electric transport, etc. That's why most of these decisions and recommendations might be fine for pretty beginner courses or presentations about the dangers of EMP at scientific conferences, but they're completely unacceptable and are outright rejected by technical specialists on the ground.

3. Nowadays, there's a complete lack of even minimal interest from the leaders of both government and private organizations in the power sector, water supply systems, communications, electric transport, and so on, to actually engage in practical protection of critical facilities against EMPs from nuclear explosions, invest their own money into it, assign their specialists to it, or upgrade equipment. And no government decrees or presidential orders can overcome the rank-and-file bureaucrats stuck in these organizations, who are always ready to report on "achievements" or come up with vague wording and solid reasons to justify the lack of progress. A typical example of such a situation is the Executive Order by U.S. President Donald Trump and the Program Status Report on the implementation of this Order, described in detail in [2], Fig. 5.

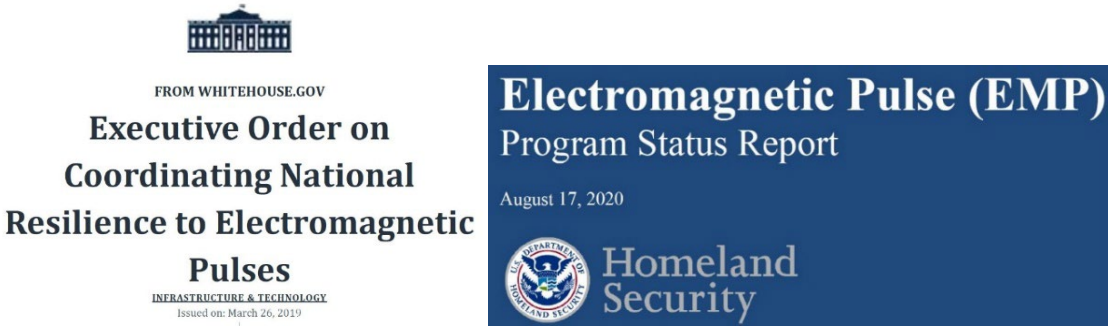

Fig. 5. Executive Order signed by President D. Trump and Report DHS about the Executive Order realization.

4. The interest of numerous government agencies, research organizations, consulting firms, and organizers of all kinds of seminars and lectures on the topic of EMP, who receive government subsidies or other types of external financial support, in keeping the EMP issue "afloat" for as long as possible (as a "cash cow") without actually solving real problems. The author has personally faced this problem.

III. What Is to Be Done?

All of the above problems are solved together and very easily, with just one government decision: creating a single National Coordination Center (NCC) in the country (5–10 leading specialists) with a technical laboratory included. Such a center should have the appropriate authority with the right to require all private and government organizations to take measures to protect their specific facilities and systems from EMPs, decide the priorities for work in the country on protecting critical infrastructure and the level of that protection, allocate funds designated for protecting critical infrastructure, and also oversee the work carried out by the organizations responsible for critical infrastructure.

Nowadays, similar NCCs exist in many countries in the field of cybersecurity, and their experience could be adopted for creating a NCC for protection against EMP. Funding for protection measures can only be partially provided by the government. The main financial burden should be borne by the CIF organizations responsible for the uninterrupted and reliable operation of their equipment.

The technical lab within the NCC should be made up of a team of independent technical specialists and professionals who have hands-on experience in power engineering, water supply systems, electric transport, and telecommunications, while also being familiar with EMP issues and the ways to protect against them. Such a technical lab might include only about a dozen or two serious technical specialists, plus five to ten lab assistants, who would be responsible for testing the protective equipment available on the market, choosing the most suitable ones, giving practical advice, providing hands-on technical help to the CIF engineering staff in using them in specific systems, and also develop their own protective equipment. A set of new protective equipment, developed by the author and specifically designed for critical civil infrastructure, along with the experience he has accumulated, could serve as a good foundation for the initial stage of such a lab.

According to the author's belief and based on his many years of personal experience creating numerous EMP protection means, his long work within a state energy company, as well as his role as the head of a private company, and his interactions with management of ministries and government agencies, this longstanding problem can't be solved in the country without establishing the single coordinating center described above.

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Author Profile

Dr. Vladimir I. Gurevich worked during 25 years at Israel Electric Corp. as a Senior specialist and Head of section of the Central Electric Laboratory.
He is the author of more than 200 professional papers and 18 books and holder of nearly 120 patents in the field of electrical engineering, power electronics, EMP protection of critical civilian infrastructures.